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Research Note

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BIOASSAY OF ALPINE MINE SPOILS FOR PLANT GROWTH AND DEVELOPMENT¹

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ABSTRACT

We studied the effects of various soil amendments on the growth and development of two grass species growing in mine spoils. The spoil material came from the McLaren Mine on the Beartooth Plateau in southern Montana and is representative of upper-subalpine and alpine mines present on large areas of the western U.S. The results show that amendments do not have a significant effect on seed germination or plant emergence. Fertilizer and manure applications do, however, significantly increase plant growth and development, and particularly the number of culms and leaves, plant height, leaf area, and shoot and root production per plant. The particular spoils studied were not very acidic, hence, lime treatments were not effective. Two species were studied that appear to have broad adaptability for revegetation of high elevation disturbances; a native, tufted hairgrass (*Deschampsia caespitosa* L.), and an introduced species, Garrison meadow foxtail (*Alopecurus pratensis* L.).

KEYWORDS: mine spoils bioassay, revegetation, soil amendments, tufted hairgrass (*Deschampsia caespitosa* L.), Garrison meadow foxtail (*Alopecurus pratensis* L.), alpine environments, plant growth and development.

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The accelerated rate at which alpine ecosystems are being disturbed in the western U.S. focuses concern on the need to develop applicable revegetation techniques. Unfortunately, only a few studies have documented rehabilitation efforts of alpine disturbances. The limiting environmental factors resulting from disturbance in the alpine zone have been well documented (Billings 1973; Brown and others 1978b; Johnston and others 1975). Also, some of the plant species that appear to be adapted to alpine disturbances have been identified (Brown and others 1978a; Brown and Johnston 1978, 1979; Greller 1974; Harrington 1946; Marr and others 1974; Willard and Marr 1970, 1971). The responses of these plant species in terms of growth and development to specific techniques and soil amendments are, for the most part, still unknown.

Mineral exploration and mining are particularly disruptive in the alpine zone, and often result in the exposure of acid spoil materials that are limiting to plant growth. Other types of disturbance such as recreation, grazing, road construction and others may, however, be more extensive (Brown and others 1978b). These spoil materials typically contain high concentrations of toxic heavy metals and a high proportion of coarse fragments that result in low water-holding capacity and a poor nutrient capital. These limiting edaphic factors appear to be common to mine spoils in the alpine zone throughout the Rocky Mountains, including the states of Montana, Idaho, Utah, Wyoming, and Colorado (Brown and Johnston 1976, 1978; Marr and others 1974). Typical examples include the numerous abandoned mine and exploration sites in this region, such as the McLaren Mine in southern Montana. A considerable amount of research in developing revegetation techniques has been done on this mine because it is representative of acid spoil conditions in western alpine areas (Brown and Johnston 1976, 1978, 1979; Brown and others 1978a, 1978b; Johnston and others 1975; Van Kekerix and others 1979).

In addition to these limiting conditions, alpine areas are characterized by severe climatic environments. Such factors as short growing seasons, cool summer temperatures, frequent frost action, high winds, and high solar radiation loads are common (Billings and Mooney 1968; Brown and others 1976; Johnston and others 1975; Willard 1976). These factors, when combined with those conditions typical of mine spoils, greatly restrict the number of adapted plant species capable of completing their entire life cycles on alpine disturbances.

Only a small fraction of the total native alpine flora in the western U.S. appears to be adapted to conditions on disturbed sites (Brown and others 1978a). Of these, however, tufted hairgrass (*Deschampsia caespitosa* L.) appears to be the single most important native species for alpine revegetation (Brown and Johnston 1978, 1979; Marr and others 1974). In addition, Garrison meadow foxtail (*Alopecurus pratensis* L.) appears to be one of the best adapted introduced species that is commercially available (Brown and others 1978a).

Revegetation research in the alpine zone has stressed the essential role of fertilizer as an amendment (Brown and Johnston 1976). Virtually no documentation is available of the role played by other common amendments such as lime and organic matter. Van Kekerix and others (1979) found that the incorporation of peat moss and the use of jute netting significantly improved seedling growth, survival, and water relations of two grass species on the McLaren Mine. In order to extend the rather limited scope of small plot studies that have been done in the past to large scale revegetation of alpine disturbances, quantitative evaluations of such amendments are needed. This is particularly important since so little is known about the growth and development responses of native species to revegetation methods.

This study documents the effects of various soil amendments on plant growth and development in McLaren Mine spoils.

METHODS

Representative spoil material was collected from the McLaren Mine in 1975. The spoil material was sieved through a 0.25 in (0.6 cm) screen to separate out the large rocks. The sieved material was then separated into seven equal fractions to which various amendments were incorporated. Previous field plot research on the McLaren Mine (Brown and Johnston 1976) suggested that certain soil amendments may be beneficial for plant establishment and growth in these spoil materials. A total of seven treatments (or amendments), each replicated four times, were prepared. These included:

1. Control: no amendments added to the spoils material.
2. Fertilizer: a granular 18-24-6 N-P-K ratio fertilizer was incorporated into the spoil at the equivalent rate to provide 0.005 percent N, or about 100 lb N per acre (111 kg N per ha).
3. Fertilizer-lime: fertilizer was added as in 2 above, plus hydrated lime was incorporated at an equivalent rate of 2,000 lb per acre (2 240 kg per ha), to raise soil pH.
4. Fertilizer-lime-straw: fertilizer and lime amendments were added as described above. Straw was added at an equivalent rate of 5 percent by volume.
5. Fertilizer-straw: fertilizer and straw were added as described above.
6. Fertilizer-lime-manure: fertilizer and lime amendments were added as described above. Manure was added at an equivalent rate of 5 percent by volume.
7. Fertilizer-manure: fertilizer and steer manure were added as described above.

Each of the seven spoil fractions, together with their incorporated amendments, were used to fill four polypropylene containers (for a total of 28 containers). These containers, each with 3 drain holes in the bottom, were 12.75 in long, 10.75 in wide, and 4.5 in deep with a volume of 617 in³ (32.4 cm X 27.3 cm X 11.4 cm = 10 084 cm³).

A composite sample of each spoil fraction was collected for soil analyses after the addition of the amendments. Previous experience with these spoils (Brown and Johnston 1976; Johnston and others 1975) had shown that the spoil materials on the McLaren Mine are acid-bearing pyrites containing high concentrations of some heavy metals such as copper and iron. Each of the spoil samples was analyzed for soil texture, saturation percentage, soluble salts, pH, and p/m of P, K, Fe, Cu, and SO₄.

Seeds of tufted hairgrass and Garrison meadow foxtail were planted in equally spaced rows in each container at a depth of 0.25 in (0.6 cm). Three rows of each species were planted, 20 seeds per row, for a total of 60 seeds per species. The sequence of the two species in the rows was randomly selected for each container to reduce bias of plant position in the containers. The seeds were planted at uniform intervals along the long axis of the containers.

The 28 containers were randomly positioned on a greenhouse bench to reduce the effect of environmental gradients. Environmental conditions within the greenhouse were controlled with a day/night temperature range of $72^{\circ}\text{F} \pm 5^{\circ}\text{F}$ day, $60^{\circ}\text{F} \pm 3^{\circ}\text{F}$ night ($22^{\circ}\text{C} \pm 3^{\circ}\text{C}/16^{\circ}\text{C} \pm 1.5^{\circ}\text{C}$) with a 12-hour photoperiod supplemented with artificial fluorescent and incandescent lighting. Relative humidity varied from lows of 35 percent during the day to highs of about 75 percent at night. Temperature and relative humidity were recorded with a calibrated Belfort³ hygrothermograph. Solar flux densities were also recorded, with a Belfort pyroheliograph, and reached peaks of $0.6\text{ cal cm}^{-2}\text{ min}^{-1}$ at midday.

The containers were watered regularly with a fine-mist spray to reduce surface disturbance due to water drop impact. The soil was maintained at near field capacity throughout the study to avoid any influence due to water stress. Prior to seedling emergence, the surface soil was kept moist on a daily basis, but after emergence watering frequency was reduced to a schedule that maintained field capacity in the root zone.

After seedling emergence, weekly counts of the number of plants in each row and their total height were recorded. The study was terminated 10 weeks following emergence when the plants had reached an advanced tillering stage of vegetative development. At this point each of the surviving plants had achieved approximately the same level of development, although not of growth, normally reached after one full growing season under field conditions. Each individual plant of both species from each container was then carefully analyzed for the following characteristics: total number of culms; total number of leaves; plant height; total leaf area; dry weight root production; and dry weight shoot production. Leaf area was determined with a Lambda Area Meter³ (model LI-3000) using the green tissue prior to drying. The roots were separated from the soil particles by hand using a gentle spray of water and slight agitation. The roots and the shoots were oven-dried at 80°C (176°F) for 24 hours, and then were immediately weighed on a top-loading balance to the nearest 0.01 g.

Analysis of variance and Hartley's multiple range test were used to identify significant differences in plant responses due to the amendments (Snedcor 1966).

RESULTS AND DISCUSSION

The results of this study are summarized in figures 1 through 5, and show that the greatest levels of plant growth and development are achieved under the highest levels of soil fertility. Generally, amendments including both fertilizer and manure resulted in the greatest average number of culms and leaves, leaf area, the greatest average plant height, and shoot and root production for both species studied. The average number of plants and the shoot root ratio, however, were not significantly different among treatments.

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The data means were plotted in bar graph form in figures 1 through 5 to provide a visual evaluation of the effects of each amendment. Figure 1 shows the effect of the various amendments on plant number (emergence and survival) for both species. Analysis of variance results show no significant effect of the amendments; however, the data do reflect the higher germination rates and plant vigor of Garrison meadow foxtail compared to tufted hairgrass.

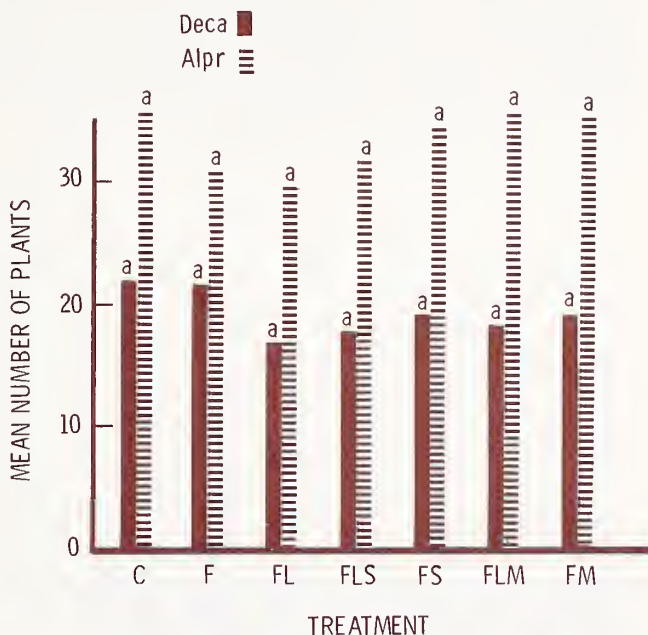


Figure 1.--Mean number of plants of tufted hairgrass (Deca) and Garrison meadow foxtail (Alpr) for each soil amendment. Abbreviations include: C, control; F, fertilizer; L, lime; S, straw; and M, manure. Treatment effects with the same letter do not differ significantly at the 95 percent level. Comparisons are only valid for each species, not between species.

The average number of culms (stems) per plant of both species, as affected by treatment, is illustrated in figure 2. The response of both species shows a strong relationship with increased levels of fertility. The data show that tufted hairgrass produced more culms per plant than Garrison meadow foxtail under all soil amendments. Although differences were statistically significant among the amendments containing lime and straw with fertilizer for both species, the largest increases were achieved when manure and fertilizer were combined.

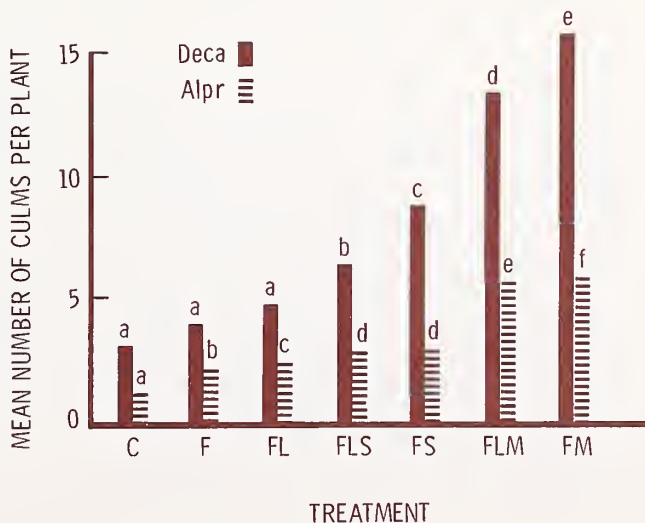


Figure 2.--Mean number of culms per plant of tufted hairgrass (Deca) and Garrison meadow foxtail (Alpr) for each soil amendment. Abbreviations include: C, control; F, fertilizer; L, lime; S, straw; and M, manure. Treatment effects with the same letter do not differ significantly at the 95 percent level. Comparisons are only valid for each species, not between species.

The average number of leaves per plant and the average leaf area per plant are illustrated in figure 3 (A and B, respectively). Both of these parameters reach their highest values under the fertilizer and manure treatments. The strong morphological differences between the two species are reflected by a comparison of number of leaves per plant and average leaf area. Tufted hairgrass has nearly twice as many leaves per plant, but Garrison meadow foxtail has nearly six times the leaf area. Of interest, too, is the effect that the amendments had on the average leaf area per leaf (divide mean leaf area by mean number of leaves); with tufted hairgrass the average area per individual leaf increases by a factor of three times from the control to the fertilizer-manure treatment, whereas with Garrison meadow foxtail it increases by a factor of about nine times. This provides some quantitative indication of how much enhanced soil fertility affects plant response.

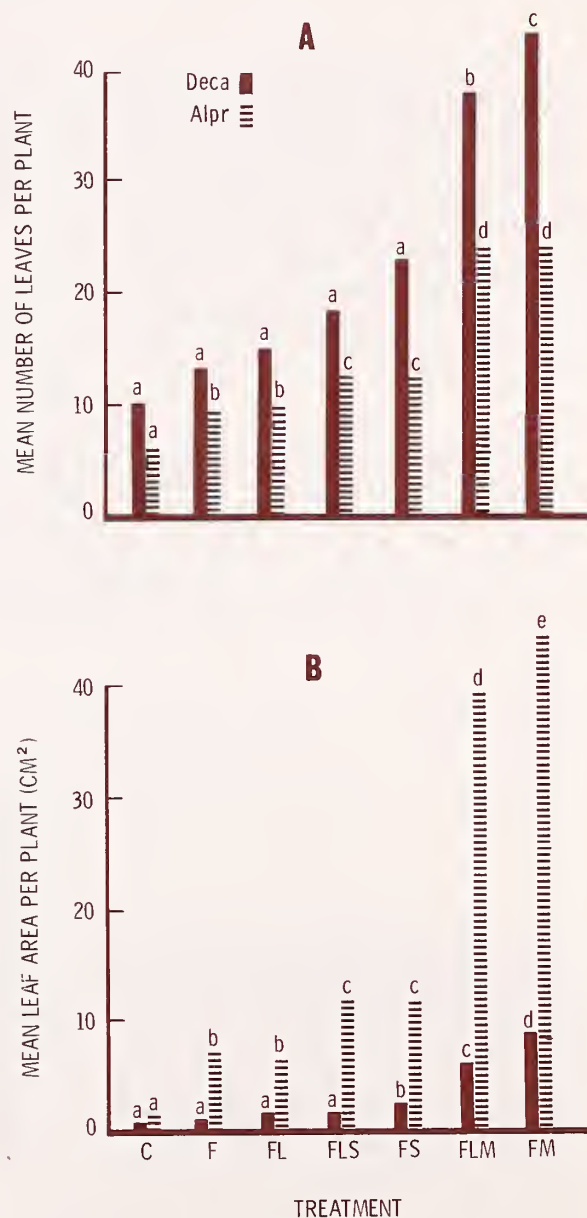


Figure 3.--Mean number of leaves per plant (A) and mean leaf area per plant in cm^2 (B) for tufted hairgrass (Deca) and Garrison meadow foxtail (Alpr) for each soil amendment. Abbreviations include: C, control; F, fertilizer; L, lime; S, straw; and M, manure. Treatment effects with the same letter do not differ significantly at the 95 percent level. Comparisons are only valid for each species, not between species.

Spoil amendments significantly increased plant height of both species (fig. 4). Tufted hairgrass did not respond as dramatically as Garrison meadow foxtail, but this reflects the strong morphological differences between the two species. Generally, tufted hairgrass is a much smaller and shorter plant than Garrison meadow foxtail when grown under similar conditions.

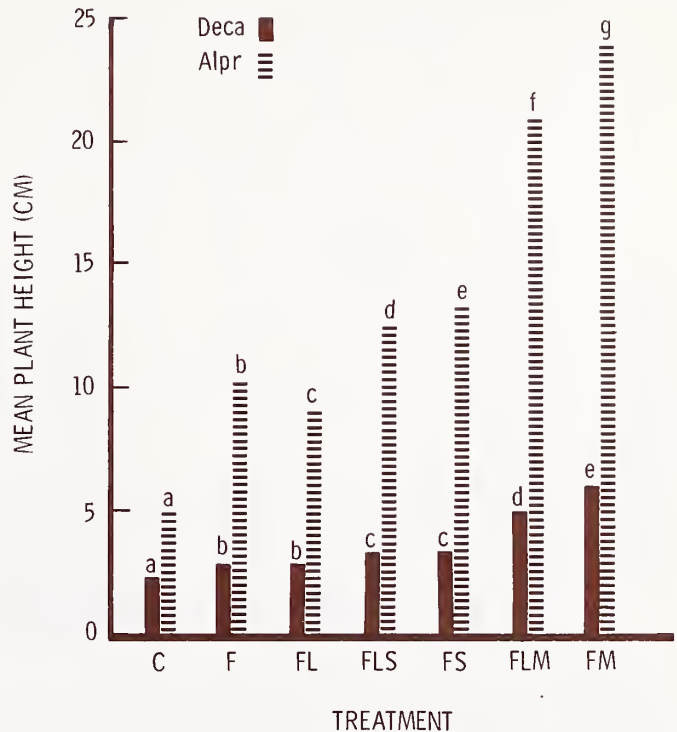


Figure 4.--Mean plant height (cm) of tufted hairgrass (Deca) and Garrison meadow foxtail (Alpr) for each soil amendment. Abbreviations include: C, control; F, fertilizer; L., lime; S, straw; and M, manure. Treatment effects with the same letter do not differ significantly at the 95 percent level. Comparisons are only valid for each species, not between species.

Dry weight production of the shoots and roots, and the shoot-root ratio, as affected by the soil amendments, are illustrated in figure 5 (A, B, and C, respectively). The greatest response of shoot and root production per plant for both species occurred in treatments containing both fertilizer and manure, although lime and straw did enhance production significantly over the control treatment in some cases. Interestingly, however, the shoot-root ratio was not affected significantly by any of the soil amendments, indicating that both shoot and root production of both species responded similarly to the treatments.

The use of lime as an amendment resulted in some unexpected effects. Normally, spoil material from the McLaren Mine is quite acid, with a pH range of 2.0 to 4.5 being quite common. However, the spoil material collected and used in this study had a much higher pH (6.1) than anticipated (table 1). It appears that lime had somewhat of a depressing effect on many of the growth and development variables of both species. For example, the fertilizer-manure amendment resulted in larger, more developed plants than the fertilizer-lime-manure amendment. Similar responses were noted with the fertilizer-lime-straw and fertilizer-lime treatments. Tufted hairgrass is apparently adapted to moderately acid conditions (Brown and Johnston 1976), which suggests that the addition of lime may be detrimental when the pH is already relatively high. The adaptability of Garrison meadow foxtail is not as well known, but the results here indicate that it may have similar characteristics.

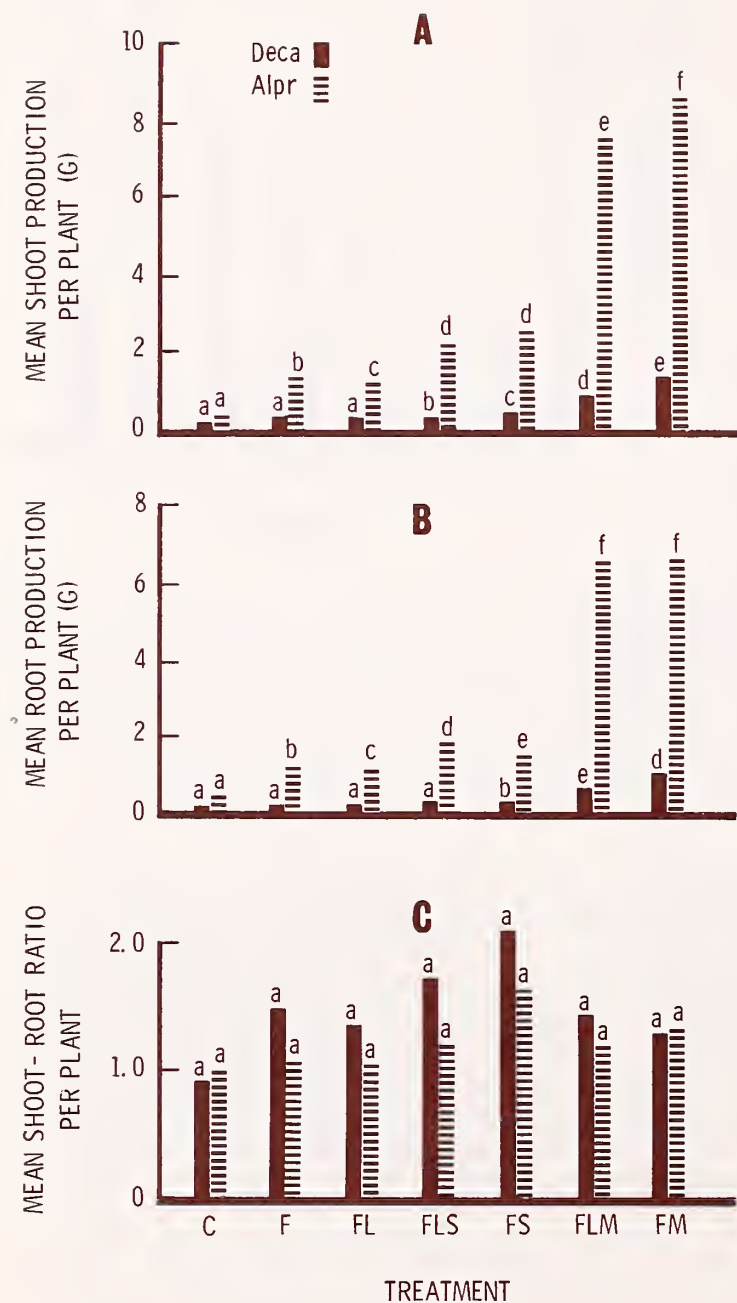


Figure 5.--Mean shoot (A) and root (B) production (dry wt. g) per plant, and mean shoot-root ratio per plant (C) for tufted hairgrass (Deca) and Garrison meadow foxtail (Alpr) for each soil amendment. Abbreviations include: C, control; F, fertilizer; L, lime; S, straw; and M, manure. Treatment effects with the same letter do not differ significantly at the 95 percent level. Comparisons are only valid for each species, not between species.

Table 1.--Some physical and chemical properties of McLaren Mine spoils and the effect of soil amendments on them

Soil amendment	Soil texture	Saturation	Soluble salt ECe*	pH	Parts per million				
					P	K	Fe	Cu	SO ₄
		Percent							
Control	Sandy-clay loam	41.3	2.8	6.1	3	58	38	29	239
Fertilizer	Loam	42.6	3.2	6.7	5	97	29	20	215
Fertilizer-lime	Sandy-clay loam	41.1	2.8	6.7	5	95	29	24	212
Fertilizer-lime-straw	Sandy-clay loam	43.1	1.9	6.7	4	97	30	24	229
Fertilizer-straw	Sandy-clay loam	42.5	2.8	6.3	3	120	30	23	233
Fertilizer-lime-manure	Loam	44.7	3.6	6.9	7	430	26	22	246
Fertilizer-manure	Sandy-clay loam	42.1	4.4	6.6	10	490	33	12	234

* Electrical conductivity, mmhos per cm.

Straw, incorporated as an organic amendment into the spoil, generally resulted in greater levels of growth and development than the control or fertilizer treatments. It was not, however, as effective as manure, presumably because of its low nutrient value and because it may have tended to tie up available soil nitrogen. Straw is probably an effective organic constituent in some cases, but in this study it did not appear to impart any favorable characteristics to the spoil material in terms of increased saturation percentage, pH, or other soil factors (table 1). The role of straw in revegetation of alpine disturbances is probably more important as a surface mulch to retard evaporation and to reduce the incidence of frost action in the soil. Methods and rates of application of these various amendments are discussed by Brown and Johnston (1978, 1979), and by Brown and others (1978a).

The soil data in table 1 suggest that only fertilizer and manure appreciably affected the soil characteristics examined compared to those in the control treatment. The availability of P and K appear to have been increased substantially by the manure and fertilizer amendments. Lime apparently caused an increase in pH, but this may not have been significant. The soil amendments did not appear to significantly affect any of the other spoil characteristics sufficiently to affect plant growth.

Interpretation of these data must be tempered with caution. For example, the data suggest that Garrison meadow foxtail, by virtue of its much higher production and growth, would be more desirable for revegetation than tufted hairgrass. What the data do not illustrate, however, is the overall adaptability to high elevation site conditions. Research and field observations clearly document the broad adaptability of tufted hairgrass to alpine disturbances and the relatively poorer long-term performance of Garrison meadow foxtail (Brown and Johnston 1976; Brown and others 1976; Marr and others 1974). Bioassay studies, such as reported here, are only capable of evaluating plant responses to edaphic factors, but they are not designed, nor are they intended, to evaluate interactions with other limiting factors such as climatic variables. Environmental conditions in the field are infinitely more complex than those reproduced in this greenhouse study. Consequently, comparisons between these data and actual field trials may be somewhat different.

CONCLUSIONS

Increasing fertility of the raw spoil material significantly improved plant growth and development of both tufted hairgrass and Garrison meadow foxtail. The results of this study, together with field data collected in previous research (Brown and Johnston 1976, 1978; Brown and others 1976, 1978a), showed that when fertilizer and manure are incorporated into the spoil material plant growth and development can be substantially improved. Because both fertilizer and manure are readily available commercially, and because of the obvious improvement of plant growth and development resulting from them, it is recommended that both be included in revegetation efforts in alpine areas. Although soil analyses should be made prior to revegetation, it is apparent from this study, as well as many others, that fertility is one of the most important limiting factors affecting the successful establishment of a self-sustaining plant cover.

The use of lime and straw amendments should be based on local site conditions. Lime should only be used when spoil pH is lower than 5.5 (e.g., under acid conditions where the solubility of heavy metals is toxic for plant growth and when essential nutrients are unavailable). Application rates will vary with spoil characteristics and should be determined by spoil analysis. Straw is most useful as a surface mulch, especially when tacked down with either netting or one of the various chemicals commercially available for this purpose. Straw incorporated into the spoil is probably not as effective as manure because it tends to reduce the available nitrogen in the soil by increasing the carbon-nitrogen ratio.

PUBLICATIONS CITED

- Billings, W. D.
1973. Arctic and alpine vegetation: similarities, differences, and susceptibility to disturbance. *BioScience* 23:697-704.
- Billings, W. D., and H. A. Mooney.
1968. The ecology of arctic and alpine plants. *Biol. Rev.* 43:481-529.
- Brown, R. W., and R. S. Johnston.
1976. Revegetation of an alpine mine disturbance: Beartooth Plateau, Montana. USDA For. Serv. Res. Note INT-206, 8 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.
- Brown, R. W., and R. S. Johnston.
1978. Rehabilitation of a high elevation mine disturbance. *In Proc. High Altitude Revegetation Workshop No. 3.* p. 116-130. *Environ. Resour. Cent., Colo. State Univ., Fort Collins, Info. Series No. 28.*
- Brown, R. W., and R. S. Johnston.
1979. Revegetation of disturbed alpine rangelands. *In Special management needs of alpine ecosystems.* p. 76-94. D. A. Johnson, ed. *Soc. Range Manage.*
- Brown, R. W., R. S. Johnston, B. Z. Richardson, and E. E. Farmer.
1976. Rehabilitation of alpine disturbances: Beartooth Plateau, Montana. *In Proc. High Altitude Revegetation Workshop No. 2.* p. 58-73. *Environ. Resour. Cent., Colo. State Univ., Fort Collins, Info. Series No. 21.*
- Brown, R. W., R. S. Johnston, and D. A. Johnson.
1978a. Rehabilitation of alpine tundra disturbances. *J. Soil Water Conserv.* 33:154-160.
- Brown, R. W., R. S. Johnston, and K. Van Cleve.
1978b. Rehabilitation problems in alpine and arctic regions. *In Reclamation of drastically disturbed lands.* p. 23-44. *Am. Soc. Agron., Madison, Wisc.*
- Greller, A. M.
1974. Vegetation of roadcut slopes in the tundra of Rocky Mountain National Park, Colorado. *Biol. Conserv.* 6:84-93.

Harrington, H. D.

1946. Results of a seeding experiment at high altitudes in the Rocky Mountain National Park. *Ecology* 27:375-377.

Johnston, R. S., R. W. Brown, and J. Cravens.

1975. Acid mine rehabilitation problems at high elevations. *In Watershed management: Proceedings of a symposium.* p. 66-79. Am. Soc. Civil Eng., New York.

Marr, J. W., D. L. Buckner, and D. L. Johnson.

1974. Ecological modification of alpine tundra by pipeline construction. *In Proc., Workshop on Revegetation of High Altitude Disturbed Lands.* p. 10-23. Environ. Resour. Cent., Colo. State Univ., Fort Collins, Info. Series 10.

Snedcor, G. W.

1966. Statistical methods. 5th ed. 534 p. Iowa State Univ. Press, Ames.

Van Kekerix, L. K., R. W. Brown, and R. S. Johnston.

1979. Seedling water relations of two grass species on high-elevation acid mine spoils. USDA For. Serv. Res. Note INT-262, 17 p.

Willard, B. E.

1976. High elevation reclamation, nuts and bolts. *In Proc. High Altitude Revegetation Workshop No. 2.* p. 1-3. Environ. Resour. Cent., Colo. State Univ., Fort Collins, Info. Series 21.

Willard, B. E., and J. W. Marr.

1970. Effects of human activities on alpine tundra ecosystems in Rocky Mountain National Park. *Biol. Conserv.* 2:257-265.

Willard, B. E., and J. W. Marr.

1971. Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. *Biol. Conserv.* 3:181-190.

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